# PATENT ABSTRACTS OF JAPAN

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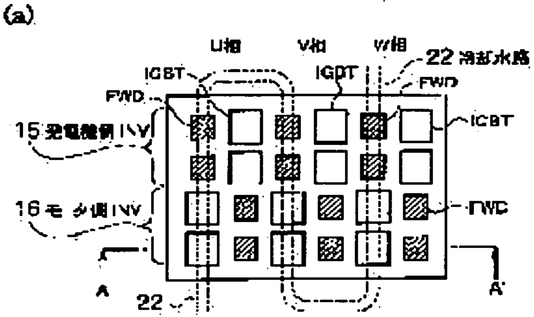
## (54) COOLING DEVICE FOR POWER MODULE

(57)Abstract:
PROBLEM TO BE SOLVED: To perform miniaturization without damaging the cooling performance of a power module in an SHEV system.
SOLUTION: The reflux diode FWD of an inverter 15 on a power generator side and the switching element IGBT of a motor side inverter 16 are arrayed on one straight line on a cooling plate 21 for each phase, and coolant piping 22 is turned to a meandering structure so as to pass through only a part right below the straight array for each phase. Thus, the passage length of a coolant flow passage is shortened, the number of times of bending the flow passage is reduced, power for coolant distribution by a cooling pump is reduced, the size of a cooling system is reduced, and costs are lowered.

(a)

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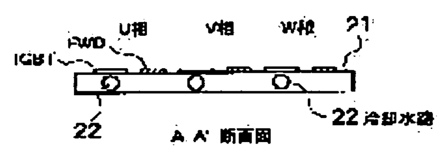


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## CLAIMS

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[Claim(s)]
[Claim 1] The switching element and reflux diode of a generator side inverter which change a generator output into a direct current power, In the power module which accumulated the switching element and reflux diode of a motor side inverter which change the direct current power of the aforementioned generator side inverter into ac power, and are supplied to the motor for a vehicles drive on the same cooling plate The cooling system of the power module characterized by having arranged the reflux diode of the inverter by the side of the aforementioned generator, and the switching element of the aforementioned motor side inverter on the straight line on the aforementioned cooling plate for every phase, and arranging coolant piping along with the aforementioned linear array for every phase.
[Claim 2] The cooling system of the power module according to claim 1 characterized by having arranged the switching element of the aforementioned generator side inverter, and the reflux diode of the aforementioned motor side inverter on the straight line on the aforementioned cooling plate for every phase, and making thickness for the direct lower part of a linear array with the switching element for each [ these ] phase of every and reflux diode in the aforementioned cooling plate thicker than other portions.
[Claim 3] The switching element and reflux diode of a generator side inverter which change a generator output into a direct current power, In the power module which accumulated the switching element and reflux diode of a motor side inverter which change the direct current power of the aforementioned generator side inverter into ac power, and are supplied to the motor for a vehicles drive on the same cooling plate The reflux diode of the inverter by the side of the aforementioned generator and the switching element of the aforementioned motor side inverter are arranged on the 1st [ on the aforementioned cooling plate ] straight line for every phase. The switching element of the aforementioned generator side inverter, and the reflux diode of the aforementioned motor side inverter for every phase Arrange on the 2nd straight line which is concurrent with the 1st straight line of the above on the aforementioned cooling plate, and coolant piping is arranged along with the 1st linear array of the above for every phase. The cooling system of the power module which makes thickness for the direct lower part of the linear array of the above 2nd for every phase in the aforementioned cooling plate thicker than other portions, and is characterized by forming the slot which enlarges thermal resistance at the both sides of the thick portion concerned.

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[Translation done.]

## DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] this invention relates to the cooling system of a power module.
[0002]
[Description of the Prior Art] A switching element and reflux diode are constructed to a bridge for every phase, and what was indicated by JP,9-92762,A is conventionally known as a cooling system of the power module which cools a power semiconductor device in the power module which has arranged the bridge of a total phase on the same substrate.
[0003] The cooling system of this conventional power module forms direct passage in the interior of the metal substrate of the bottom near each power semiconductor device, and it miniaturizes the size of the whole power module while raising refrigeration capacity by passing a coolant to the passage.
[0004]
[Problem(s) to be Solved by the Invention] it is possible to apply as a cooling system of the power semiconductor device of the inverter portion of the SHIRIZUHAIBURIDDO vehicle ("SHEV" is called hereafter.) which consists of motors for a vehicles drive by which a rotation drive is carried out with the ac power which the generator [ AC generator ] side inverter which changes this Prior art and changes this generator output into a direct current power, for example, the motor side inverter which carries out the reconversion of the direct current power of this generator side inverter to ac power, and this motor side inverter output, and it shows this to drawing 5
[0005] In the cooling system of this power module, a generator side inverter (INV), IGBT as a switching element of each phase of each motor side inverter (INV) is arranged in a straight line on the cooling substrate 1. The reflux diode (fly wheel diode : FWD) of the generator side INV and each of each phase by the side of [ INV ] a motor moreover, on the cooling substrate 1 It is the structure which is made concurrent with the array of IGBT, arranges in a straight line, one cooling water way 2 is made to wind, and arranges so that it may pass near directly under [ of each array of the cooling substrate 1 ], is made to carry out conduction of the cooling water 3 with the cooling pump 4 as a coolant into this cooling water way 2, and carries out a heat removal with the external heat exchanger 5.
[0006] However, like especially SHEV, with the inverter equipment for large power with large loss, when the heat from a power semiconductor device tends to be diffused and extended and it is going to lower thermal resistance, the superficial interval of the increase of thickness and each semiconductor device of the metal cooling substrate 1 is needed, and there is a possibility that the whole equipment may be enlarged.
[0007] Then, in order to make thickness of the cooling substrate 1 thin as much as possible and to cool each semiconductor device on the average, as shown in above-mentioned drawing 5 and above-mentioned drawing 6 , the cooling water way 2 will be formed directly under each semiconductor device, and the heat from a semiconductor device will be directly made into the structure which radiates heat to the cooling water 3 in the cooling water way 2.

[0008] Also in the structure of such a cooling system, although the bore of the cooling water way 2 must be made small for the miniaturization of equipment, if the cooling water way 2 of such a diameter of a narrow is formed directly under many semiconductor devices, the whole cooling water way length becomes long, system-pressure loss increases, a cooling water pump will be enlarged and the power which drives the cooling water pump of a parenthesis will also increase.
[0009] Moreover, if cooling water piping 2 is made to move in a zigzag direction repeatedly as shown in drawing 5 and drawing 6 , the amount of elbow will also increase [ pressure loss ]. Therefore, although the number of times of a knee of the cooling water way 2 has the fewer possible desirable one, if it is going to let cooling water piping pass directly under all semiconductor devices for a modular miniaturization, the amount of [ many ] elbow can do and it will cause increase of pressure loss.
[0010] this invention aims at offering the cooling system of the power module which can attain a miniaturization, without having been made in view of such a Prior-art-technical problem, and spoiling a cooling performance.
[0011]
[Means for Solving the Problem] The cooling system of the power module of invention of a claim 1 The switching element and reflux diode of a generator side inverter which change a generator output into a direct current power, In the power module which accumulated the switching element and reflux diode of a motor side inverter which change the direct current power of the aforementioned generator side inverter into ac power, and are supplied to the motor for a vehicles drive on the same cooling plate The reflux diode of the inverter by the side of the aforementioned generator and the switching element of the aforementioned motor side inverter are arranged on the straight line on the aforementioned cooling plate for every phase, and it is characterized by arranging coolant piping along with the aforementioned straight line for every phase.
[0012] In the cooling system of the power module of a claim 1, invention of a claim 2 arranges the switching element of the aforementioned generator side inverter, and the reflux diode of the aforementioned motor side inverter on the straight line on the aforementioned cooling plate for every phase, and is characterized by making thickness for the direct lower part of a linear array with the switching element for each [ these ] phase of every and reflux diode in the aforementioned cooling plate thicker than other portions.
[0013] The cooling system of the power module of invention of a claim 3 The switching element and reflux diode of a generator side inverter which change a generator output into a direct current power, In the power module which accumulated the switching element and reflux diode of a motor side inverter which change the direct current power of the aforementioned generator side inverter into ac power, and are supplied to the motor for a vehicles drive on the same cooling plate The reflux diode of the inverter by the side of the aforementioned generator and the switching element of the aforementioned motor side inverter are arranged on the 1st [ on the aforementioned cooling plate ] straight line for every phase. The switching element of the aforementioned generator side inverter, and the reflux diode of the aforementioned motor side inverter for every phase Arrange on the 2nd straight line which is concurrent with the 1st straight line of the above on the aforementioned cooling plate, and coolant piping is arranged along with the 1st linear array of the above for every phase. Thickness for the direct lower part of the linear array of the above 2nd for every phase in the aforementioned cooling plate is made thicker than other portions, and it is characterized by forming the slot which enlarges thermal resistance at the both sides of the heavy-gage portion concerned.
[0014]
[Effect of the Invention] In the cooling system of the power module of invention of a claim 1 By arranging the reflux diode of the inverter by the side of a generator, and the switching element of a motor side inverter on the straight line on a cooling plate for every phase, and making it the structure where coolant piping was arranged along with the aforementioned linear array for every phase The way length of coolant passage can be shortened, and the number of times of a knee of passage can be lessened, power for coolant conduction with a cooling pump is made small,

size of a cooling system is made small, and reduction of cost can be aimed at.
[0015] In the cooling system of the power module of invention of a claim 2 In addition to the effect of the invention of a claim 1, the switching element of a generator side inverter and the reflux diode of a motor side inverter are arranged on the straight line on a cooling plate for every phase. By having made thickness for the direct lower part of a linear array with the switching element for each [ these ] phase of every and reflux diode in a cooling plate thicker than other portions, the heat capacity for those array direct lower parts can be enlarged, and the temperature rise of those semiconductor devices can be stopped low.
[0016] In the cooling system of the power module of invention of a claim 3 The reflux diode of the inverter by the side of a generator and the switching element of a motor side inverter are arranged on the 1st [ on a cooling plate ] straight line for every phase. The switching element of a generator side inverter, and the reflux diode of a motor side inverter for every phase Arrange on the 2nd straight line which is concurrent with the 1st straight line on a cooling plate, and coolant piping is arranged along with the 1st linear array for every phase. By having made thickness for the direct lower part of the linear array of the 2nd for every phase in a cooling plate thicker than other portions, and having formed in the both sides of the heavy-gage portion concerned the slot which enlarges thermal resistance Things are made. invention of a claim 1, and the effect of the invention of a claim 2 -- in addition, the heat for the direct lower part of the 2nd linear array is not conducted into a coolant piping portion by the slot -- as -- ****** -- The refrigeration capacity of a coolant piping portion can be set as the degree of necessary minimum, consequently power of a cooling pump can be made small, size of a cooling system can be made small, and equipment cost can be reduced.
[0017]
[Embodiments of the Invention] Hereafter, the form of operation of this invention is explained in full detail based on drawing. First, a series hybrid electric vehicle (SHEV) is explained with reference to drawing 1 . SHEV drives AC generator 13 by ICE11 rather than drives the direct tire 12 with an internal combustion engine (ICE) like a gasoline engine, drives a motor 14 by the generated output of this generator 13, and drives a tire 12 by this motor 14.
[0018] And in order to change the alternating current generated output of a generator 13 into the direct current power of a constant voltage and to change into desired ac power again, the generator side inverter (INV) 15 and the motor side inverter (INV) 16 are formed. In addition, 19 is a smoothing capacitor.
[0019] In order that the these generators and motor side [ INV16 ] INV15 may all perform the interconversion of a three-phase-circuit ac and dc, it is equipped with the bridge circuit of IGBT and reflux diode (fly wheel diode : FWD) as a power switching element for U, V, and W each phase of every, and converts the power of a request by carrying out PWM switching control of these IGBT(s).
[0020] Since such a SHEV system becomes possible [ not needing the conventional mechanical change gear and also operating ICE11 efficiently only for power generation ], it has various merits, such as improvement in mpg, and improvement in the flexibility of an equipment layout.
[0021] If the operation situation of a SHEV system is considered here, although it will become the flow of electrical energy called a power generation -> drive regularly, in order that a generator 13 and a motor 14 may generally perform an efficient operation control, the power-factor serves as operation near 1 by -1 and the motor 14 with the generator 13. Although inverters 15 and 16 usually consist of a power switching element like IGBT, and parallel connection of FWD, a power-factor is [ the remarkable rate of a power loss ] the portion of FWD in the -1 (power generation) state, and a power-factor breaks out in the one (drive) state conversely in the portion of a switching element [ like IGBT ] whose remarkable rate of a power loss is. And although this rate changes with the values of IGBT, the switching loss of FWD, and regular loss, when usage whose switching loss is quite lower than regular loss is carried out, it becomes remarkable [ the difference ].
[0022] The PWM carrier frequency of the inverter 16 which generally drives the motor 14 for vehicles is several kHz - about 10kHz, a switching loss is in a few state in many cases compared with regular loss, and, in such a case, the difference of the power consumed between IGBT and

FWD becomes large. Therefore, when steady operation is taken into consideration, within the same inverter 16, the need for cooling [ FWD ] of the IGBT is large.

[0023] Contrary to steady operation, operation in case power energy flows is taken into consideration. For example, in order to start ICE11, the case where a generator 13 is driven as a motor, and the case where a motor 14 is used instead of a generator as regeneration operation for storing slowdown energy in a cell etc. are equivalent to this. In this case, the power-factor of each inverters 15 and 16 becomes the opposite of the time of steady operation, a power-factor becomes about one, a power loss will mainly be generated in IGBT, in the motor side INV16, a power-factor becomes about -one and a power loss will mainly be generated by FWD at the generator side INV15. Therefore, considering cooling in this case, it is necessary to mainly cool IGBT in the generator side INV15, and to mainly cool FWD in the motor side INV16.

[0024] However, such reverse operation is not regularly generated in a SHEV system. For example, it is easy to design time to supply [ to use a generator 13 as a drive motor, in order to start ICE11, and ] a maximum current at 1 or less second, and it is easy on control for regeneration operation using a motor 14 as a generator to also stop the peak current of regeneration, and to shorten duration very much.

[0025] If the peculiarity of such a SHEV system is taken into consideration, maximum-power loss will occur regularly and it will become possible by so carrying out conduction of the coolant near directly under [ of it ] to a power semiconductor device with remarkable generation of heat to design a cooling system so that neither of the skin temperatures of the semiconductor devices may exceed Tjmax (the maximum temperature of junction) by cooling intensively.

[0026] in this case, what is necessary is just to make it the cooling structure which a longitudinal direction is made to heat-transfer to the place of the element by making the element with which maximum-power loss is comparatively alike, and does not cool by the coolant directly about a small element, but is intensively cooled by the conduction of a coolant adjoin Although thermal resistance will become high by it, since maximum-power loss is originally small, it is possible to stop Tjmax uniformly. Moreover, even when maximum-power loss of the semiconductor device in which coolant passage does not exist near directly under is of the same grade as the semiconductor device in which it exists near directly under, the design which holds down the temperature rise of a semiconductor device to below Tjmax with the heat capacity of the metal substrate directly under a semiconductor device itself for the reason mentioned above since it is an ultrashort potato is possible for the duration in the state where maximum-power loss occurs.

[0027] Based on this consideration, the cooling system of the power module of the gestalt of operation of the 1st of this invention was made into the structure shown in <u>drawing 2</u> . Namely, IGBT and reflux diode (FWD) as a power switching element of U [ by the side of / INV15 / the generator which changes the dc output of AC generator 13 into a direct current power ], V, and W each phase, As opposed to the power module which accumulated IGBT of each phase by the side of [ INV16 ] the motor which carries out the reconversion of the direct current power by the side of [ INV15 ] a generator to ac power, and is supplied to the motor 15 for a vehicles drive, and FWD on the same cooling substrate 21 FWD by the side of [ INV15 ] a generator and IGBT by the side of [ INV16 ] a motor are arranged on the 1st [ on the cooling substrate 21 ] straight line for U, V, and W each phase of every, and it is made to move in a zigzag direction so that it may pass only along a part for the direct lower part of the 1st linear array of the cooling water way 22 which carries out conduction of the cooling water which is a coolant for every phase. And it connects with a heat exchanger 5 like the conventional example shown in <u>drawing 5</u> , and this cooling water way 22 carries out conduction of the cooling water with the cooling pump 4.

[0028] In addition, the remaining power semiconductor devices, i.e., IGBT by the side of [ INV15 ] a generator and FWD by the side of [ INV16 ] a motor, are arranged on the 2nd straight line which is concurrent with the 1st straight line on the cooling substrate 21 for every phase.

[0029] Since the number of times of the knee of the cooling water way 22 decreases to 2 times (counting with 1 time at 180 degrees) from 5 times and way length's is decreasing to the half mostly by this as compared with the cooling water way 2 of the conventional example shown in <u>drawing 5</u> and <u>drawing 6</u> , the pressure loss of a cooling pump falls and the miniaturization of a

pump is attained so.
[0030] The calculation result supposing the relation between pressure loss and a flow rate is more concretely shown in the graph of drawing 3 . The cooling water way equivalent to the conventional example which made five pieces the number of parts of the elbow at which width of face of 12mm, a height of 6mm, and way length turn at 1482mm and 180 degrees by making a passage cross section into the shape of a rectangle (1), The result which asked for the relation between a flow rate and a pressure loss about the cooling water way (2) which made way length the half length (741mm = 1482mm/2) like the gestalt of this operation, and made the number of parts of an elbow two pieces is the graph of drawing 3 . A bird clapper understands a pressure loss mostly by the cooling water way of the gestalt of this operation at a half so that clearly from the graph of this drawing 3 .
[0031] The temperature rise by the heat which the flow in piping of cooling water became smooth, and the heat-removal performance improved so much by this, and the cooling water of a under [ piping ] absorbed will also be stopped, and absorption of the heat from a semiconductor device can also be performed so much effectively.
[0032] Next, the gestalt of operation of the 2nd of this invention is explained based on drawing 4 . The gestalt of the 2nd operation uses as a heavy-gage part 23 a part for the direct lower part of the linear array of the 2nd of a power semiconductor device [ in / the cooling substrate 21 / further / to the structure of the gestalt of the 1st operation ] to which it was shown in drawing 2 , and is characterized by forming the slot 24 for raising thermal resistance to the both sides. In addition, arrangement of the cooling water way 22 is the same as that of the gestalt of the 1st operation.
[0033] Generation of heat of the power semiconductor device on the 2nd linear array which was shown in drawing 2 and in which the cooling water way 22 is not established with the structure of the gestalt of the 1st operation is comparatively large, and when there is a possibility that duration may be long and may exceed the maximum temperature Tjmax of junction, it is made the structure of the gestalt of this 2nd operation.
[0034] Thus, when the cooling water way 22 enlarges the heat capacity to the semiconductor device on the 2nd linear array which is not formed near directly under by the heavy-gage part 23, even if time for a power loss to continue somewhat becomes long, it is possible to suppress elevation of element temperature.
[0035] Moreover, by forming a slot 24 between the 2nd linear array in the cooling substrate 21, and the 1st linear array which is concurrent with this, lateral thermal resistance can be enlarged and decline in the efficiency-heat transfer rate in the cooling water way 22 can be prevented.
[0036] That is, although parameters, such as a minimum flow rate of the cooling water which should be poured in a channel, and a pressure loss to generate, are decided only in order to stop the temperature rise of the semiconductor device which should radiate heat on the cooling water way 22 by Tjmax, if the thermal resistance of the longitudinal direction of the cooling substrate 21 is low on structure when the approaching semiconductor device generates heat, the invasion of a heat flow rate on the cooling water way 22 from a longitudinal direction will arise, and the case where it must stop having to perform a heat exchange on the and -- in order to correspond to this -- the heat transfer rate in the cooling water way 22 -- excessive -- it must raise -- a setting flow rate and a pressure loss -- not increasing -- finally it will be necessary to obtain but to increase cooling pumping power, and the cost of a cooling system will go up as the result, and size will also become large
[0037] However, if it is made the structure which enlarges lateral thermal resistance and prevents decline in the efficiency-heat transfer rate in the cooling water way 22 by forming a slot 24 like the gestalt of this operation, the invasion of a heat flow rate on the cooling water way 22 from a longitudinal direction can be suppressed, and the problem mentioned above can be avoided.
[0038] In addition, with the gestalt of operation mentioned above, although the power module of a three-phase-circuit alternating current was explained, not only a three phase circuit but when it uses for example, for two phases, the same effect is brought about.
[0039] Moreover, although it was made to make one cooling water way wind, after the cooling

water way where one cooling water way was distributed by the cooling pump side (entrance side), and was each distributed passes along a part for the direct lower part of the in-line arrangement for every phase by the gestalt of operation mentioned above, it is collected and delivered, and you may make it return to a heat exchanger. Moreover, it may be directly collected and delivered with a heat exchanger in this case.

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[Translation done.]

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TECHNICAL FIELD

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[The technical field to which invention belongs] this invention relates to the cooling system of a power module.

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[Translation done.]

* NOTICES *



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## PRIOR ART

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[Description of the Prior Art] A switching element and reflux diode are constructed to a bridge for every phase, and what was indicated by JP,9-92762,A is conventionally known as a cooling system of the power module which cools a power semiconductor device in the power module which has arranged the bridge of a total phase on the same substrate.
[0003] The cooling system of this conventional power module forms direct passage in the interior of the metal substrate of the bottom near each power semiconductor device, and it miniaturizes the size of the whole power module while raising refrigeration capacity by passing a coolant to the passage.

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[Translation done.]

## EFFECT OF THE INVENTION

[Effect of the Invention] In the cooling system of the power module of invention of a claim 1 By arranging the reflux diode of the inverter by the side of a generator, and the switching element of a motor side inverter on the straight line on a cooling plate for every phase, and making it the structure where coolant piping was arranged along with the aforementioned linear array for every phase The way length of coolant passage can be shortened, and the number of times of a knee of passage can be lessened, power for coolant conduction with a cooling pump is made small, size of a cooling system is made small, and reduction of cost can be aimed at.
[0015] In the cooling system of the power module of invention of a claim 2 In addition to the effect of the invention of a claim 1, the switching element of a generator side inverter and the reflux diode of a motor side inverter are arranged on the straight line on a cooling plate for every phase. By having made thickness for the direct lower part of a linear array with the switching element for each [ these ] phase of every and reflux diode in a cooling plate thicker than other portions, the heat capacity for those array direct lower parts can be enlarged, and the temperature rise of those semiconductor devices can be stopped low.
[0016] In the cooling system of the power module of invention of a claim 3 The reflux diode of the inverter by the side of a generator and the switching element of a motor side inverter are arranged on the 1st [ on a cooling plate ] straight line for every phase. The switching element of a generator side inverter, and the reflux diode of a motor side inverter for every phase Arrange on the 2nd straight line which is concurrent with the 1st straight line on a cooling plate, and coolant piping is arranged along with the 1st linear array for every phase. By having made thickness for the direct lower part of the linear array of the 2nd for every phase in a cooling plate thicker than other portions, and having formed in the both sides of the heavy-gage portion concerned the slot which enlarges thermal resistance Things are made. invention of a claim 1, and the effect of the invention of a claim 2 -- in addition, the heat for the direct lower part of the 2nd linear array is not conducted into a coolant piping portion by the slot -- as -- ****** -- The refrigeration capacity of a coolant piping portion can be set as the degree of necessary minimum, consequently power of a cooling pump can be made small, size of a cooling system can be made small, and equipment cost can be reduced.
[0017]
[Embodiments of the Invention] Hereafter, the form of operation of this invention is explained in full detail based on drawing. First, a series hybrid electric vehicle (SHEV) is explained with reference to drawing 1 . SHEV drives AC generator 13 by ICE11 rather than drives the direct tire 12 with an internal combustion engine (ICE) like a gasoline engine, drives a motor 14 by the generated output of this generator 13, and drives a tire 12 by this motor 14.
[0018] And in order to change the alternating current generated output of a generator 13 into the direct current power of a constant voltage and to change into desired ac power again, the generator side inverter (INV) 15 and the motor side inverter (INV) 16 are formed. In addition, 19 is a smoothing capacitor.
[0019] In order that the these generators and motor side [ INV16 ] INV15 may all perform the interconversion of a three-phase-circuit ac and dc, it is equipped with the bridge circuit of IGBT and reflux diode (fly wheel diode : FWD) as a power switching element for U, V, and W each

phase of every, and converts the power of a request by carrying out PWM switching control of these IGBT(s).
[0020] Since such a SHEV system becomes possible [ not needing the conventional mechanical change gear and also operating ICE11 efficiently only for power generation ], it has various merits, such as improvement in mpg, and improvement in the flexibility of an equipment layout.
[0021] If the operation situation of a SHEV system is considered here, although it will become the flow of electrical energy called a power generation -> drive regularly, in order that a generator 13 and a motor 14 may generally perform an efficient operation control, the power-factor serves as operation near 1 by -1 and the motor 14 with the generator 13. Although inverters 15 and 16 usually consist of a power switching element like IGBT, and parallel connection of FWD, a power-factor is [ the remarkable rate of a power loss ] the portion of FWD in the -1 (power generation) state, and a power-factor breaks out in the one (drive) state conversely in the portion of a switching element [ like IGBT ] whose remarkable rate of a power loss is. And although this rate changes with the values of IGBT, the switching loss of FWD, and regular loss, when usage whose switching loss is quite lower than regular loss is carried out, it becomes remarkable [ the difference ].
[0022] The PWM carrier frequency of the inverter 16 which generally drives the motor 14 for vehicles is several kHz - about 10kHz, a switching loss is in a few state in many cases compared with regular loss, and, in such a case, the difference of the power consumed between IGBT and FWD becomes large. Therefore, when steady operation is taken into consideration, within the same inverter 16, the need for cooling [ FWD ] of the IGBT is large.
[0023] Contrary to steady operation, operation in case power energy flows is taken into consideration. For example, in order to start ICE11, the case where a generator 13 is driven as a motor, and the case where a motor 14 is used instead of a generator as regeneration operation for storing slowdown energy in a cell etc. are equivalent to this. In this case, the power-factor of each inverters 15 and 16 becomes the opposite of the time of steady operation, a power-factor becomes about one, a power loss will mainly be generated in IGBT, in the motor side INV16, a power-factor becomes about -one and a power loss will mainly be generated by FWD at the generator side INV15. Therefore, considering cooling in this case, it is necessary to mainly cool IGBT in the generator side INV15, and to mainly cool FWD in the motor side INV16.
[0024] However, such reverse operation is not regularly generated in a SHEV system. For example, it is easy to design time to supply [ to use a generator 13 as a drive motor, in order to start ICE11, and ] a maximum current at 1 or less second, and it is easy on control for regeneration operation using a motor 14 as a generator to also stop the peak current of regeneration, and to shorten duration very much.
[0025] If the peculiarity of such a SHEV system is taken into consideration, maximum-power loss will occur regularly and it will become possible by so carrying out conduction of the coolant near directly under [ of it ] to a power semiconductor device with remarkable generation of heat to design a cooling system so that neither of the skin temperatures of the semiconductor devices may exceed Tjmax (the maximum temperature of junction) by cooling intensively.
[0026] in this case, what is necessary is just to make it the cooling structure which a longitudinal direction is made to heat-transfer to the place of the element by making the element with which maximum-power loss is comparatively alike, and does not cool by the coolant directly about a small element, but is intensively cooled by the conduction of a coolant adjoin Although thermal resistance will become high by it, since maximum-power loss is originally small, it is possible to stop Tjmax uniformly. Moreover, even when maximum-power loss of the semiconductor device in which coolant passage does not exist near directly under is of the same grade as the semiconductor device in which it exists near directly under, the design which holds down the temperature rise of a semiconductor device to below Tjmax with the heat capacity of the metal substrate directly under a semiconductor device itself for the reason mentioned above since it is an ultrashort potato is possible for the duration in the state where maximum-power loss occurs.
[0027] Based on this consideration, the cooling system of the power module of the gestalt of operation of the 1st of this invention was made into the structure shown in drawing 2 . Namely, IGBT and reflux diode (FWD) as a power switching element of U [ by the side of / INV15 / the

generator which changes the dc output of AC generator 13 into a direct current power ], V, and W each phase, As opposed to the power module which accumulated IGBT of each phase by the side of [ INV16 ] the motor which carries out the reconversion of the direct current power by the side of [ INV15 ] a generator to ac power, and is supplied to the motor 15 for a vehicles drive, and FWD on the same cooling substrate 21 FWD by the side of [ INV15 ] a generator and IGBT by the side of [ INV16 ] a motor are arranged on the 1st [ on the cooling substrate 21 ] straight line for U, V, and W each phase of every, and it is made to move in a zigzag direction so that it may pass only along a part for the direct lower part of the 1st linear array of the cooling water way 22 which carries out conduction of the cooling water which is a coolant for every phase. And it connects with a heat exchanger 5 like the conventional example shown in drawing 5 , and this cooling water way 22 carries out conduction of the cooling water with the cooling pump 4.
[0028] In addition, the remaining power semiconductor devices, i.e., IGBT by the side of [ INV15 ] a generator and FWD by the side of [ INV16 ] a motor, are arranged on the 2nd straight line which is concurrent with the 1st straight line on the cooling substrate 21 for every phase.
[0029] Since the number of times of the knee of the cooling water way 22 decreases to 2 times (counting with 1 time at 180 degrees) from 5 times and way length's is decreasing to the half mostly by this as compared with the cooling water way 2 of the conventional example shown in drawing 5 and drawing 6 , the pressure loss of a cooling pump falls and the miniaturization of a pump is attained so.
[0030] The calculation result supposing the relation between pressure loss and a flow rate is more concretely shown in the graph of drawing 3 . The cooling water way equivalent to the conventional example which made five pieces the number of parts of the elbow at which width of face of 12mm, a height of 6mm, and way length turn at 1482mm and 180 degrees by making a passage cross section into the shape of a rectangle (1), The result which asked for the relation between a flow rate and a pressure loss about the cooling water way (2) which made way length the half length (741mm = 1482mm/2) like the gestalt of this operation, and made the number of parts of an elbow two pieces is the graph of drawing 3 . A bird clapper understands a pressure loss mostly by the cooling water way of the gestalt of this operation at a half so that clearly from the graph of this drawing 3 .
[0031] The temperature rise by the heat which the flow in piping of cooling water became smooth, and the heat-removal performance improved so much by this, and the cooling water of a under [ piping ] absorbed will also be stopped, and absorption of the heat from a semiconductor device can also be performed so much effectively.
[0032] Next, the gestalt of operation of the 2nd of this invention is explained based on drawing 4 . The gestalt of the 2nd operation uses as a heavy-gage part 23 a part for the direct lower part of the linear array of the 2nd of a power semiconductor device [ in / the cooling substrate 21 / further / to the structure of the gestalt of the 1st operation ] to which it was shown in drawing 2 , and is characterized by forming the slot 24 for raising thermal resistance to the both sides. In addition, arrangement of the cooling water way 22 is the same as that of the gestalt of the 1st operation.
[0033] Generation of heat of the power semiconductor device on the 2nd linear array which was shown in drawing 2 and in which the cooling water way 22 is not established with the structure of the gestalt of the 1st operation is comparatively large, and when there is a possibility that duration may be long and may exceed the maximum temperature Tjmax of junction, it is made the structure of the gestalt of this 2nd operation.
[0034] Thus, when the cooling water way 22 enlarges the heat capacity to the semiconductor device on the 2nd linear array which is not formed near directly under by the heavy-gage part 23, even if time for a power loss to continue somewhat becomes long, it is possible to suppress elevation of element temperature.
[0035] Moreover, by forming a slot 24 between the 2nd linear array in the cooling substrate 21, and the 1st linear array which is concurrent with this, lateral thermal resistance can be enlarged and decline in the efficiency-heat transfer rate in the cooling water way 22 can be prevented.
[0036] That is, although parameters, such as a minimum flow rate of the cooling water which

should be poured in a channel, and a pressure loss to generate, are decided only in order to stop the temperature rise of the semiconductor device which should radiate heat on the cooling water way 22 by Tjmax, when the approaching semiconductor device generates heat, the case where the invasion of a heat flow rate on the cooling water way 22 from a structure top low and a longitudinal direction arises, and the thermal resistance of the longitudinal direction of the cooling substrate 21 must stop having to perform a heat exchange on the cooling water way and -- in order to correspond to this -- the heat transfer rate in the cooling water way 22 -- excessive -- it must raise -- a setting flow rate and a pressure loss -- not increasing -- finally it will be necessary to obtain but to increase cooling pumping power, and the cost of a cooling system will go up as the result, and size will also become large

[0037] However, if it is made the structure which enlarges lateral thermal resistance and prevents decline in the efficiency-heat transfer rate in the cooling water way 22 by forming a slot 24 like the gestalt of this operation, the invasion of a heat flow rate on the cooling water way 22 from a longitudinal direction can be suppressed, and the problem mentioned above can be avoided.

[0038] In addition, with the gestalt of operation mentioned above, although the power module of a three-phase-circuit alternating current was explained, not only a three phase circuit but when it uses for example, for two phases, the same effect is brought about.

[0039] Moreover, although it was made to make one cooling water way wind, after the cooling water way where one cooling water way was distributed by the cooling pump side (entrance side), and was each distributed passes along a part for the direct lower part of the in-line arrangement for every phase by the gestalt of operation mentioned above, it is collected and delivered, and you may make it return to a heat exchanger. Moreover, it may be directly collected and delivered with a heat exchanger in this case.

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[Translation done.]

## TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] it is possible to apply as a cooling system of the power semiconductor device of the inverter portion of the SHIRIZUHAIBURIDDO vehicle ("SHEV" is called hereafter.) which consists of motors for a vehicles drive by which a rotation drive is carried out with the ac power which the generator [ AC generator ] side inverter which changes this Prior art and changes this generator output into a direct current power, for example, the motor side inverter which carries out the reconversion of the direct current power of this generator side inverter to ac power, and this motor side inverter output, and it shows this to drawing 5
[0005] In the cooling system of this power module, a generator side inverter (INV), IGBT as a switching element of each phase of each motor side inverter (INV) is arranged in a straight line on the cooling substrate 1. The reflux diode (fly wheel diode : FWD) of the generator side INV and each of each phase by the side of [ INV ] a motor moreover, on the cooling substrate 1 It is the structure which is made concurrent with the array of IGBT, arranges in a straight line, one cooling water way 2 is made to wind, and arranges so that it may pass near directly under [ of each array of the cooling substrate 1 ], is made to carry out conduction of the cooling water 3 with the cooling pump 4 as a coolant into this cooling water way 2, and carries out a heat removal with the external heat exchanger 5.
[0006] However, like especially SHEV, with the inverter equipment for large power with large loss, when the heat from a power semiconductor device tends to be diffused and extended and it is going to lower thermal resistance, the superficial interval of the increase of thickness and each semiconductor device of the metal cooling substrate 1 is needed, and there is a possibility that the whole equipment may be enlarged.
[0007] Then, in order to make thickness of the cooling substrate 1 thin as much as possible and to cool each semiconductor device on the average, as shown in above-mentioned drawing 5 and above-mentioned drawing 6 , the cooling water way 2 will be formed directly under each semiconductor device, and the heat from a semiconductor device will be directly made into the structure which radiates heat to the cooling water 3 in the cooling water way 2.
[0008] Also in the structure of such a cooling system, although the bore of the cooling water way 2 must be made small for the miniaturization of equipment, if the cooling water way 2 of such a diameter of a narrow is formed directly under many semiconductor devices, the whole cooling water way length becomes long, system-pressure loss increases, a cooling water pump will be enlarged and the power which drives the cooling water pump of a parenthesis will also increase.
[0009] Moreover, if cooling water piping 2 is made to move in a zigzag direction repeatedly as shown in drawing 5 and drawing 6 , the amount of elbow will also increase [ pressure loss ]. Therefore, although the number of times of a knee of the cooling water way 2 has the fewer possible desirable one, if it is going to let cooling water piping pass directly under all semiconductor devices for a modular miniaturization, the amount of [ many ] elbow can do and it will cause increase of pressure loss.
[0010] this invention aims at offering the cooling system of the power module which can attain a miniaturization, without having been made in view of such a Prior-art-technical problem, and

spoiling a cooling performance.

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[Translation done.]

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## MEANS

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[Means for Solving the Problem] The cooling system of the power module of invention of a claim 1 The switching element and reflux diode of a generator side inverter which change a generator output into a direct current power, In the power module which accumulated the switching element and reflux diode of a motor side inverter which change the direct current power of the aforementioned generator side inverter into ac power, and are supplied to the motor for a vehicles drive on the same cooling plate The reflux diode of the inverter by the side of the aforementioned generator and the switching element of the aforementioned motor side inverter are arranged on the straight line on the aforementioned cooling plate for every phase, and it is characterized by arranging coolant piping along with the aforementioned straight line for every phase.
[0012] In the cooling system of the power module of a claim 1, invention of a claim 2 arranges the switching element of the aforementioned generator side inverter, and the reflux diode of the aforementioned motor side inverter on the straight line on the aforementioned cooling plate for every phase, and is characterized by making thickness for the direct lower part of a linear array with the switching element for each [ these ] phase of every and reflux diode in the aforementioned cooling plate thicker than other portions.
[0013] The cooling system of the power module of invention of a claim 3 The switching element and reflux diode of a generator side inverter which change a generator output into a direct current power, In the power module which accumulated the switching element and reflux diode of a motor side inverter which change the direct current power of the aforementioned generator side inverter into ac power, and are supplied to the motor for a vehicles drive on the same cooling plate The reflux diode of the inverter by the side of the aforementioned generator and the switching element of the aforementioned motor side inverter are arranged on the 1st [ on the aforementioned cooling plate ] straight line for every phase. The switching element of the aforementioned generator side inverter, and the reflux diode of the aforementioned motor side inverter for every phase Arrange on the 2nd straight line which is concurrent with the 1st straight line of the above on the aforementioned cooling plate, and coolant piping is arranged along with the 1st linear array of the above for every phase. Thickness for the direct lower part of the linear array of the above 2nd for every phase in the aforementioned cooling plate is made thicker than other portions, and it is characterized by forming the slot which enlarges thermal resistance at the both sides of the heavy-gage portion concerned.

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[Translation done.]

## DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] The circuit block diagram showing the general SHEV structure of a system.
[Drawing 2] The plan and cross section showing the structure of the gestalt of operation of the 1st of this invention.
[Drawing 3] The graph which shows the piping property of the cooling water way and the cooling water way of the conventional example by the gestalt of the 1st operation of the above.
[Drawing 4] The plan and cross section showing the structure of the gestalt of operation of the 2nd of this invention.
[Drawing 5] The perspective diagram showing the structure of the conventional example.
[Drawing 6] The plan showing the structure of the conventional example.
[Description of Notations]
21 Cooling Substrate
22 Cooling Water Way
23 Heavy-gage Part
24 Slot

[Translation done.]

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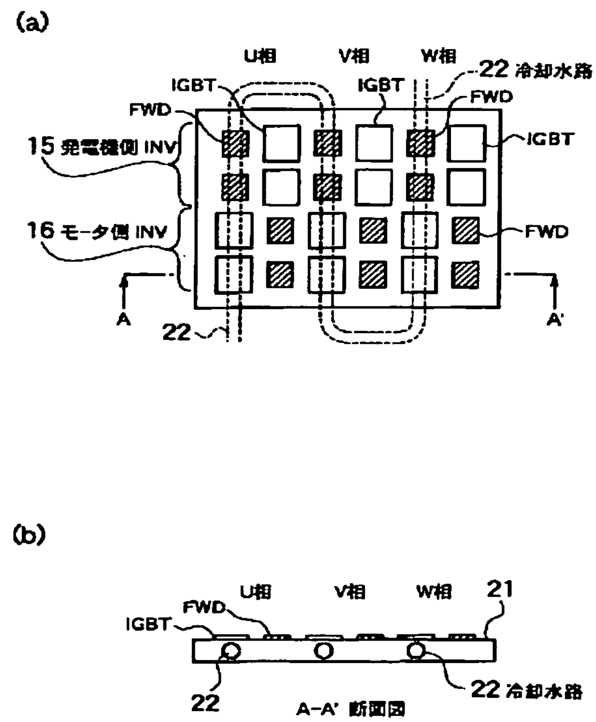
(54)【発明の名称】　パワーモジュールの冷却装置

(57)【要約】
【課題】　ＳＨＥＶシステムにおけるパワーモジュールの冷却性能を損なうことなく、小形化を図る。
【解決手段】　発電機側のインバータ１５の還流ダイオードＦＷＤとモータ側インバータ１６のスイッチング素子ＩＧＢＴとを各相ごとに冷却板２１上の一直線上に配列し、冷却材配管２２を各相ごとの前記直線配列の直下部分のみを通るように蛇行させた構造にすることにより、冷却材流路の路長を短くし、また流路の曲り回数を少なくし、冷却ポンプによる冷却材通流のための仕事率を小さくして、冷却系のサイズを小さくしてコストの低減が図れるようにした。



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【特許請求の範囲】

【請求項１】　発電機出力を直流電力に変換する発電機側インバータのスイッチング素子及び還流ダイオードと、前記発電機側インバータの直流電力を交流電力に変換して車両駆動用モータに供給するモータ側インバータのスイッチング素子及び還流ダイオードを同一の冷却板上に集積したパワーモジュールにおいて、

前記発電機側のインバータの還流ダイオードと前記モータ側インバータのスイッチング素子とを各相ごとに前記冷却板上の一直線上に配列し、冷却材配管を各相ごとの前記直線配列に沿って配置させたことを特徴とするパワーモジュールの冷却装置。

【請求項２】　前記発電機側インバータのスイッチング素子と前記モータ側インバータの還流ダイオードとを各相ごとに前記冷却板上の一直線上に配列し、前記冷却板におけるこれら各相ごとのスイッチング素子と還流ダイオードとの直線配列の直下部分の肉厚を他の部分よりも厚くしたことを特徴とする請求項１に記載のパワーモジュールの冷却装置。

【請求項３】　発電機出力を直流電力に変換する発電機側インバータのスイッチング素子及び還流ダイオードと、前記発電機側インバータの直流電力を交流電力に変換して車両駆動用モータに供給するモータ側インバータのスイッチング素子及び還流ダイオードを同一の冷却板上に集積したパワーモジュールにおいて、

前記発電機側のインバータの還流ダイオードと前記モータ側インバータのスイッチング素子とを各相ごとに前記冷却板上の第１の直線上に配列し、

前記発電機側インバータのスイッチング素子と前記モータ側インバータの還流ダイオードとを各相ごとに、前記冷却板上の前記第１直線に並行する第２の直線上に配列し、

冷却材配管を各相ごとの前記第１の直線配列に沿って配置させ、

前記冷却板における各相ごとの前記第２の直線配列の直下部分の肉厚を他の部分よりも厚くし、かつ当該肉厚部分の両側に熱抵抗を大きくする溝を形成したことを特徴とするパワーモジュールの冷却装置。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、パワーモジュールの冷却装置に関する。

【０００２】

【従来の技術】スイッチング素子と還流ダイオードとを各相ごとにブリッジに組み、同一基板上に全相のブリッジを配置したパワーモジュールにおいて、パワー半導体素子を冷却するパワーモジュールの冷却装置として、従来、特開平９－９２７６２号公報に記載されたものが知られている。

【０００３】この従来のパワーモジュールの冷却装置

2

は、各パワー半導体素子の近傍下の金属基板の内部に直接流路を形成し、冷却材をその流路に流すことにより冷却能力を向上させると共に、パワーモジュール全体の大きさを小形化するものである。

【０００４】

【発明が解決しようとする課題】この従来の技術を、例えば、交流発電機、この発電機出力を直流電力に変換する発電機側インバータ、この発電機側インバータの直流電力を交流電力に再変換するモータ側インバータ、そしてこのモータ側インバータの出力する交流電力によって回転駆動される車両駆動用モータで構成されるシリーズハイブリッド車（以下、「ＳＨＥＶ」と称する。）のインバータ部分のパワー半導体素子の冷却装置として適用することが考えられ、これを図５及び図６に示す。

【０００５】このパワーモジュールの冷却装置では、発電機側インバータ（ＩＮＶ）、モータ側インバータ（ＩＮＶ）それぞれの各相のスイッチング素子としてのＩＧＢＴを冷却基板１上に一直線に配列し、また発電機側ＩＮＶ、モータ側ＩＮＶそれぞれの各相の還流ダイオード（フライホイールダイオード：ＦＷＤ）も冷却基板１上に、ＩＧＢＴの配列に並行させて一直線に配列し、冷却基板１の各配列の直下近傍を通るように１本の冷却水路２を蛇行させて配設し、この冷却水路２内に冷却材として冷却水３を冷却ポンプ４によって通流させ、外部の熱交換器５により熱除去する構造である。

【０００６】ところが、特にＳＨＥＶのように損失の大きい大電力用のインバータ装置では、パワー半導体素子からの熱を拡散して広げ、熱抵抗を下げようとすると、金属冷却基板１の厚みが増し、かつ各半導体素子の平面的な間隔が必要となり、装置全体が大型化してしまう恐れがある。

【０００７】そこで、可能な限り冷却基板１の厚みを薄くし、各半導体素子を平均的に冷却するために、上述の図５及び図６に示すように、各半導体素子の直下に冷却水路２を設け、半導体素子からの熱を直接、冷却水路２内の冷却水３に放熱する構造にすることになる。

【０００８】このような冷却装置の構造においても、装置の小形化のためには冷却水路２の内径を小さくしなければならないが、多数の半導体素子の直下にこのような細い径の冷却水路２を設けると、全体の冷却水路長が長くなり、系の圧力損失が増大し、冷却水ポンプが大型化し、かつこの冷却水ポンプを駆動する仕事率も増大してしまう。

【０００９】また、図５及び図６に示したように冷却水配管２を何度も蛇行させると曲り部分でも圧力損失が増大してしまう。そのため冷却水路２の曲り回数はできるだけ少ない方が好ましいが、モジュールの小形化のためにすべての半導体素子の直下に冷却水配管を通そうとすると多くの曲り部分ができてしまい、圧力損失の増大の要因となる。

【００１０】本発明はこのような従来の技術的課題に鑑みてなされたもので、冷却性能を損なうことなく、小形化が図れるパワーモジュールの冷却装置を提供することを目的とする。

【００１１】

【課題を解決するための手段】請求項１の発明のパワーモジュールの冷却装置は、発電機出力を直流電力に変換する発電機側インバータのスイッチング素子及び還流ダイオードと、前記発電機側インバータの直流電力を交流電力に変換して車両駆動用モータに供給するモータ側インバータのスイッチング素子及び還流ダイオードを同一の冷却板上に集積したパワーモジュールにおいて、前記発電機側のインバータの還流ダイオードと前記モータ側インバータのスイッチング素子とを各相ごとに前記冷却板上の一直線上に配列し、冷却材配管を各相ごとの前記直線に沿って配置させたことを特徴とするものである。

【００１２】請求項２の発明は、請求項１のパワーモジュールの冷却装置において、前記発電機側インバータのスイッチング素子と前記モータ側インバータの還流ダイオードとを各相ごとに前記冷却板上の一直線上に配列し、前記冷却板におけるこれら各相ごとのスイッチング素子と還流ダイオードとの直線配列の直下部分の肉厚を他の部分よりも厚くしたことを特徴とするものである。

【００１３】請求項３の発明のパワーモジュールの冷却装置は、発電機出力を直流電力に変換する発電機側インバータのスイッチング素子及び還流ダイオードと、前記発電機側インバータの直流電力を交流電力に変換して車両駆動用モータに供給するモータ側インバータのスイッチング素子及び還流ダイオードを同一の冷却板上に集積したパワーモジュールにおいて、前記発電機側のインバータの還流ダイオードと前記モータ側インバータのスイッチング素子とを各相ごとに前記冷却板上の第１の直線上に配列し、前記発電機側インバータのスイッチング素子と前記モータ側インバータの還流ダイオードとを各相ごとに、前記冷却板上の前記第１直線に並行する第２の直線上に配列し、冷却材配管を各相ごとの前記第１の直線配列に沿って配置させ、前記冷却板における各相ごとの前記第２の直線配列の直下部分の肉厚を他の部分よりも厚くし、かつ当該厚肉部分の両側に熱抵抗を大きくする溝を形成したことを特徴とするものである。

【００１４】

【発明の効果】請求項１の発明のパワーモジュールの冷却装置では、発電機側のインバータの還流ダイオードとモータ側インバータのスイッチング素子とを各相ごとに冷却板上の一直線上に配列し、冷却材配管を各相ごとの前記直線配列に沿って配置させた構造にすることにより、冷却材流路の路長を短くし、また流路の曲り回数を少なくすることができ、冷却ポンプによる冷却材通流のための仕事率を小さくし、冷却系のサイズを小さくして、コストの低減が図れる。

【００１５】請求項２の発明のパワーモジュールの冷却装置では、請求項１の発明の効果に加えて、発電機側インバータのスイッチング素子とモータ側インバータの還流ダイオードとを各相ごとに冷却板上の一直線上に配列し、冷却板におけるこれら各相ごとのスイッチング素子と還流ダイオードとの直線配列の直下部分の肉厚を他の部分よりも厚くしたことにより、それらの配列直下部分の熱容量を大きくし、それらの半導体素子の温度上昇を低く抑えることができる。

【００１６】請求項３の発明のパワーモジュールの冷却装置では、発電機側のインバータの還流ダイオードとモータ側インバータのスイッチング素子とを各相ごとに冷却板上の第１の直線上に配列し、発電機側インバータのスイッチング素子とモータ側インバータの還流ダイオードとを各相ごとに、冷却板上の第１の直線に並行する第２の直線上に配列し、冷却材配管を各相ごとの第１の直線配列に沿って配置させ、冷却板における各相ごとの第２の直線配列の直下部分の肉厚を他の部分よりも厚くし、かつ当該厚肉部分の両側に熱抵抗を大きくする溝を形成したことにより、請求項１の発明、請求項２の発明の効果に加えて、第２の直線配列の直下部分の熱を溝によって冷却材配管部分に伝導しないように遮ぎることができ、冷却材配管部分の冷却能力を必要最低限度に設定することができ、この結果、冷却ポンプの仕事率を小さくし、冷却系のサイズを小さくし、装置コストを低減することができる。

【００１７】

【発明の実施の形態】以下、本発明の実施の形態を図に基づいて詳説する。まず、シリーズハイブリッド電気自動車（ＳＨＥＶ）について、図１を参照して説明する。ＳＨＥＶは、ガソリンエンジンのような内燃機関（ＩＣＥ）によって直接タイヤ１２を駆動するのではなく、ＩＣＥ１１で交流発電機１３を駆動し、この発電機１３の発電電力でモータ１４を駆動し、このモータ１４によってタイヤ１２を駆動する。

【００１８】そして発電機１３の交流発電電力を定電圧の直流電力に変換し、再度所望の交流電力に変換するために発電機側インバータ（ＩＮＶ）１５と、モータ側インバータ（ＩＮＶ）１６を設けている。なお、１９は平滑コンデンサである。

【００１９】これらの発電機側ＩＮＶ１５、モータ側ＩＮＶ１６は、いずれも３相交流－直流の相互変換を行うため、Ｕ，Ｖ，Ｗ各相ごとにパワースイッチング素子としてＩＧＢＴと還流ダイオード（フライホイールダイオード：ＦＷＤ）のブリッジ回路を備え、これらのＩＧＢＴをＰＷＭスイッチング制御することによって所望の電力変換を行う。

【００２０】このようなＳＨＥＶシステムは、従来の機械式変速機を必要とせず、またＩＣＥ１１も発電のためだけに効率良く運転することが可能となるため、燃費の

向上、装置レイアウトの自由度の向上等さまざまなメリットがある。

【００２１】ここでＳＨＥＶシステムの運転状況を考えると、定常的には発電→駆動といった電気エネルギの流れとなるが、一般的には発電機１３、モータ１４共に高効率運転制御を行うため、力率が発電機１３では－１、モータ１４では１に近い運転となっている。インバータ１５，１６は通常、ＩＧＢＴのようなパワースイッチング素子とＦＷＤの並列接続から構成されているが、力率が－１（発電）状態では、電力損失のかなりの割合がＦＷＤの部分で、また逆に力率が１（駆動）状態では電力損失のかなりの割合がＩＧＢＴのようなスイッチング素子の部分で発生する。そしてこの割合はＩＧＢＴとＦＷＤのスイッチング損失と定常損失の値により変化するが、スイッチング損失が定常損失よりかなり低いような使い方をした場合にその差は顕著となる。

【００２２】一般的に車両用モータ１４を駆動するインバータ１６のＰＷＭキャリア周波数は数ｋＨｚ～１０ｋＨｚ程度であり、スイッチング損失が定常損失に比べて少ない状態であることが多く、このような場合にはＩＧＢＴとＦＷＤとの間で消費される電力の差は大きくなる。したがって、定常運転を考慮すると、同じインバータ１６内では、ＩＧＢＴの方がＦＷＤよりも冷却の必要性が大きい。

【００２３】定常運転とは逆に、電力エネルギが流れるときの動作を考慮する。例えば、ＩＣＥ１１をスタートさせるために発電機１３をモータとして駆動する場合や、減速エネルギを電池などに蓄えるための回生動作としてモータ１４を発電機代わりに使用する場合がこれに相当する。この場合、各インバータ１５，１６の力率は定常運転時とは正反対になり、発電機側ＩＮＶ１５では力率が１近くになり、電力損失は主にＩＧＢＴで発生し、モータ側ＩＮＶ１６では力率が－１近くになり、電力損失は主にＦＷＤで発生することになる。したがって、この場合の冷却を考えると、発電機側ＩＮＶ１５では主にＩＧＢＴを冷却する必要があり、モータ側ＩＮＶ１６では主にＦＷＤを冷却する必要がある。

【００２４】しかしながら、このような逆の動作はＳＨＥＶシステムにおいては定常的に発生するものではない。例えば、ＩＣＥ１１をスタートさせるために発電機１３を駆動モータとして用い、最大電流を供給する時間を１秒以下に設計することは容易であるし、モータ１４を発電機として用いる回生動作も回生のピーク電流を抑え、継続時間を極短くすることは制御上容易である。

【００２５】このようなＳＨＥＶシステムの特殊性を考慮すると、定常的に最大電力損失が発生し、それゆえに発熱が顕著なパワー半導体素子に対してその直下近傍に冷却材を通流させることによって集中的に冷却することにより、いずれの半導体素子の表面温度もTjmax（接合の最大温度）を超えないように冷却系を設計することが可能となる。

【００２６】この場合、最大電力損失が比較的に小さい素子については直接に冷却材で冷却するのではなく、冷却材の通流によって集中的に冷却されている素子に隣接させることにより、その素子の所まで横方向に熱伝達させる冷却構造にすればよい。それによって熱抵抗は高くなってしまうが、本来最大電力損失が小さいので、Tjmaxを一定に抑えることが可能である。また、冷却材流路が直下近傍に存在しない半導体素子の最大電力損失が、それが直下近傍に存在する半導体素子と同程度である場合でも、最大電力損失の発生する状態の継続時間は上述した理由により極短いものであるので、半導体素子直下の金属基板そのものの熱容量で半導体素子の温度上昇をTjmax以下に抑える設計が可能である。

【００２７】かかる考察に基づき、本発明の第１の実施の形態のパワーモジュールの冷却装置は、図２に示す構造にした。すなわち、交流発電機１３の直流出力を直流電力に変換する発電機側ＩＮＶ１５のＵ，Ｖ，Ｗ各相のパワースイッチング素子としてのＩＧＢＴ及び還流ダイオード（ＦＷＤ）と、発電機側ＩＮＶ１５の直流電力を交流電力に再変換して車両駆動用モータ１５に供給するモータ側ＩＮＶ１６の各相のＩＧＢＴ及びＦＷＤを同一の冷却基板２１上に集積したパワーモジュールに対して、発電機側ＩＮＶ１５のＦＷＤとモータ側ＩＮＶ１６のＩＧＢＴとをＵ，Ｖ，Ｗ各相ごとに冷却基板２１上の第１の直線上に配列し、冷却材である冷却水を通流させる冷却水路２２を各相ごとの第１の直線配列の直下部分のみを通るように蛇行させている。そしてこの冷却水路２２は、図５に示した従来例と同様に熱交換器５に接続し、また冷却ポンプ４によって冷却水を通流させる。

【００２８】なお、残りのパワー半導体素子、つまり、発電機側ＩＮＶ１５のＩＧＢＴとモータ側ＩＮＶ１６のＦＷＤも、各相ごとに冷却基板２１上の第１の直線に並行する第２の直線上に配列している。

【００２９】これにより、図５及び図６に示した従来例の冷却水路２と比較すると、冷却水路２２の曲りの回数が５回から２回（１８０度で１回と数えて）に減り、路長もほぼ半分に減っているので、冷却ポンプの圧力損失が下がり、それだけポンプの小形化が可能となる。

【００３０】より具体的に、圧力損失と流量の関係を想定した計算結果を図３のグラフに示してある。流路断面を長方形状として幅１２ｍｍ、高さ６ｍｍ、そして路長が１４８２ｍｍ、１８０度に曲がる曲り部の個所数を５個とした従来例に相当する冷却水路（１）と、本実施の形態のように路長を半分の長さ（７４１ｍｍ＝１４８２ｍｍ／２）にし、曲り部の個所数を２個にした冷却水路（２）とについて、流量と圧損との関係を求めた結果が図３のグラフである。この図３のグラフから明らかなように、本実施の形態の冷却水路により圧損がほぼ半分になることが分かる。

【００３１】これにより、冷却水の配管中の流れが円滑になり、それだけ熱除去性能が向上し、また配管中での冷却水の吸収した熱による温度上昇も抑えられ、それだけ半導体素子からの熱の吸収も効果的に行なえることになる。

【００３２】次に、本発明の第２の実施の形態を図４に基づいて説明する。第２の実施の形態は、図２に示した第１の実施の形態の構造に対して、さらに、冷却基板２１におけるパワー半導体素子の第２の直線配列の直下部分を厚肉部２３にし、その両側に熱抵抗をあげるための溝２４を形成したことを特徴とする。なお、冷却水路２２の配置は第１の実施の形態と同様である。

【００３３】図２に示した第１の実施の形態の構造では、冷却水路２２が設けられていない第２の直線配列上のパワー半導体素子の発熱が比較的大きく、かつ継続時間が長くて接合の最大温度Tjmaxを超える恐れがあるような場合には、この第２の実施の形態の構造にする。

【００３４】このようにして、冷却水路２２が直下近傍に形成されていない第２の直線配列上の半導体素子に対する熱容量を厚肉部２３により大きくすることにより、多少電力損失の継続する時間が長くなっても素子温度の上昇を抑えることが可能である。

【００３５】また、冷却基板２１における第２の直線配列とこれに並行する第１の直線配列との間に溝２４を形成することにより、横方向の熱抵抗を大きくして冷却水路２２での実効的な熱伝達率の低下を防ぐことができる。

【００３６】すなわち、冷却水路２２で放熱すべき半導体素子の温度上昇をTjmaxで抑えるためだけに水路に流すべき冷却水の最低限の流量、発生する圧損等のパラメータは決められているが、近接する半導体素子が発熱した際に冷却基板２１の横方向の熱抵抗が構造上低いと横方向から冷却水路２２への熱流の侵入が生じ、設計以上に冷却水路２２で熱交換を行わなければならなくなる場合が発生する。そしてこれに対応するためには、冷却水路２２での熱伝達率を余計に高めねばならず、設定流量、圧損を増やさざるを得ず、最終的に冷却ポンプ能力を増大させる必要が生じ、その結果として、冷却系のコストが上昇し、またサイズも大きくなってしまう。

【００３７】しかしながら、本実施の形態のように溝２４を形成することにより、横方向の熱抵抗を大きくして冷却水路２２での実効的な熱伝達率の低下を防ぐ構造にすれば、横方向からの冷却水路２２への熱流の侵入を抑えることができ、上述した問題を避けることができるのである。

【００３８】なお、上述した実施の形態では、３相交流のパワーモジュールについて説明したが、３相に限らず、例えば、２相に用いた場合も同様の効果をもたらす。

【００３９】また、上述した実施の形態では、１つの冷却水路を蛇行させるようにしたが、１つの冷却水路が冷却ポンプ側（入口側）で分配されて、各分配された冷却水路が各相ごとの直列配列の直下部分を通った後に集配されて熱交換器へ戻るようにしてもよい。またこの場合、熱交換器にて直接に集配されてもよい。

【図面の簡単な説明】

【図１】一般的なＳＨＥＶシステムの構成を示す回路ブロック図。

【図２】本発明の第１の実施の形態の構造を示す平面図及び断面図。

【図３】上記の第１の実施の形態による冷却水路と従来例の冷却水路との配管特性を示すグラフ。

【図４】本発明の第２の実施の形態の構造を示す平面図及び断面図。

【図５】従来例の構造を示す斜視図。

【図６】従来例の構造を示す平面図。

【符号の説明】

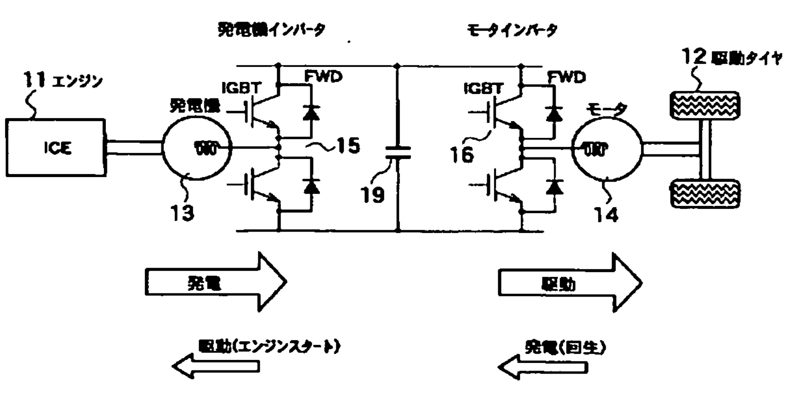
２１　冷却基板

２２　冷却水路

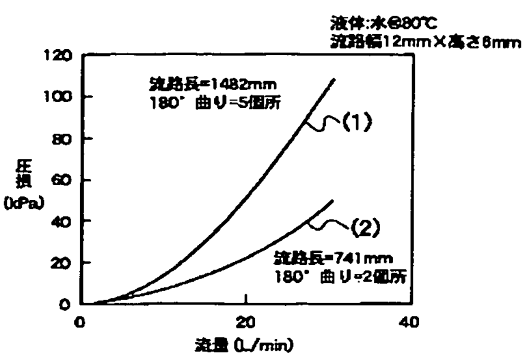
２３　厚肉部

２４　溝

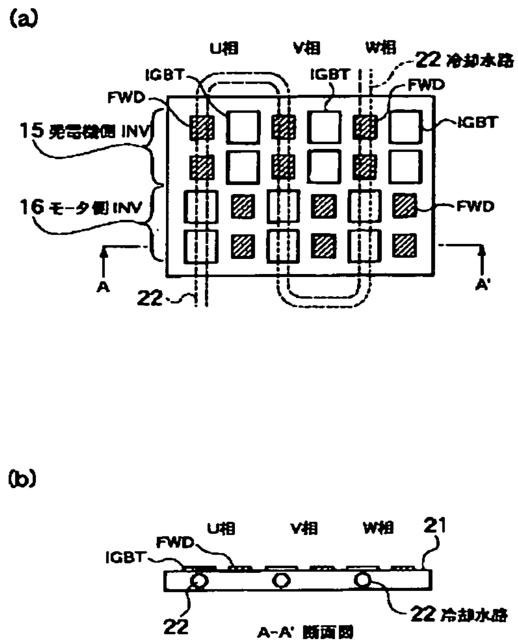
【図１】



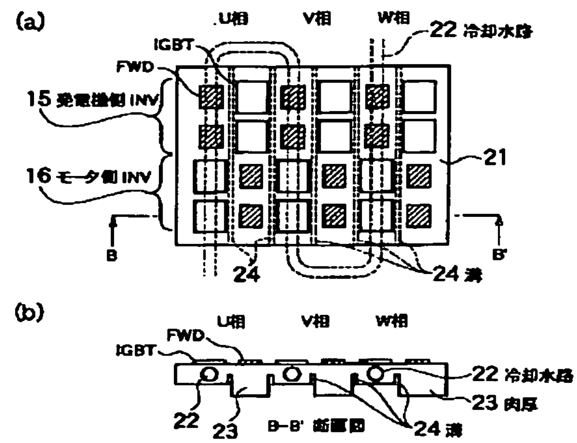

【図３】



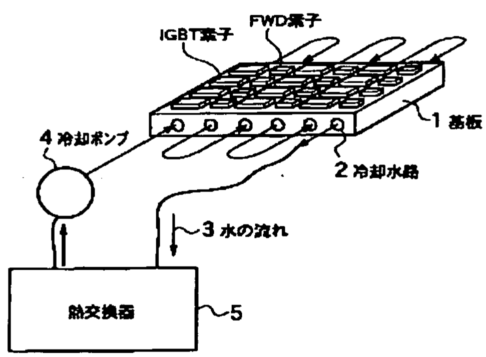
【図２】



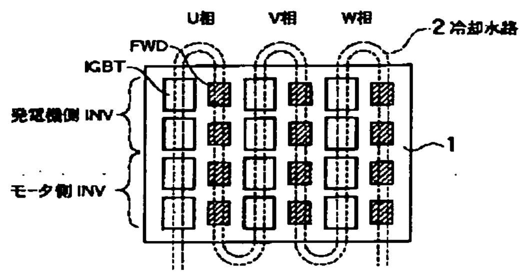

【図４】




【図５】




【図６】

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